MEASUREMENT IN SCIENCE PROJECT

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INSTRUMENTS USED TO PRESENT BASIC MEASUREMENT CONCEPTS IN SCIENCE

Teaching science to visually handicapped children, particularly through the use of laboratory methods, has long posed a problem. In regular science classes, the phenomena of the physical and biological world are encountered visually. Visual interactions may range from direct unaided observations of phenomena to observation of results of scientific manipulation which employ a variety of indirect measures. Visual displays frequently encountered in elementary science include simple linear and circular scales which characterize thermometers and balances. The blind child requires tactile interaction with these scales to understand them. Thus such scales for blind children must emphasize tactile displays.

Although many efforts have been made to make science aids for blind children more tactual, the efforts themselves have been largely unscientific. Informal surveys in the classes and schools for the visually handicapped reveal that teachers have developed many techniques and devices of greatly varying quality in order to overcome the problem of science instruction. Most of these techniques and devices have been random efforts of teachers and educators scattered across the country. The development of educational aids has not been systematic nor has development relied on existing research in measurement.

Problem

This project represents an effort of the Instructional Materials Reference Center for Visually Handicapped Children of the American Printing House for the Blind to discover and evaluate materials currently available for use by the sighted, to adapt these where possible, and to develop new materials where mecessary for the instruction of visually handicapped children. The specific task of this project was to identify basic measurement operations in science at the junior high level and to identify instruments and devices required by blind students to perform these operations. The problem of measurement in science for blind children was pointed up as a result of an informal textbook analysis of junior high science textbooks. The analysis was made to identify and evaluate the importance of illustrations and diagrams which had been omitted in braille editions. The preliminary examination suggested that a number of basic measurement concepts could be illustrated using a small number of devices.

Procedure

An exploratory textbook analysis of current seventh, eighth and ninth grade science books (in print and in braille) was made across the areas of life science, earth science and physical science. This analysis was made to discover the kinds of things measured and to identify measurement operations and instruments used in illustrating the concepts presented. The exploratory analysis included:

(1) General curriculum areas where deficits for visually handicapped occur

(2) Specific content units in each area

(3) Concepts presented and developed in each unit

(4) Specific materials and aids used to present these concepts.

Special aids and appliance catalogs for visually handicapped were examined to see if adapted or specialized measurement devices appropriate for blind children exist. Commercial catalogs were also examined to determine which devices might be adapted for use by blind children.

Results of Textbook Analysis

Measurement concepts. Measurement concepts appear most often in physical science texts but are found in a variety of presentations in all science texts analyzed, usually supplementing or illustrating explanations. The following operations illustrate basic concepts most often found in the texts examined.

(1) Using the thermometer, changes in temperature and phase changes in matter are illustrated by observing the change in a solid (ice) which becomes a liquid when heated, and eventually a gas with continued application of heat.

(2) Linear measurement with the ruler includes measurement of length and width to compute areas, and length, width, and height to find volumes.

(3) Weight measurements regularly occur. The spring balance is the instrument used most often for simple weight measurement. It is also used to explain the balance principle. For more accurate weight measurement and for measuring mass the platform or pan balance is used.

(4) Using experimental or comparison methods, mass of each of a number of blocks is determined. When masses of equal volumes are compared, density is computed and illustrated in a number of examples.

(5) Gravity and gravitational forces are demonstrated using the spring balance.

Measurement instruments. Measurement instruments which appeared most often were:

(1) The thermometer is the most frequently occuring instrument. It appears in Fahrenheit and centigrade, often with the two scales compared.

(2) Various balances, in grams and ounces, appear throughout. The simple spring balance appears most often and is the most versatile balance for sighted students. The platform or pan balance is used extensively in exercises requiring greater accuracy than that afforded by the spring balance.

(3) Rulers and measuring sticks, in inches and centimeters, are used in a variety of measurement activities.

(4) Graduates and various containers for measurement, dry and liquid, are common.

(5) Blocks of equal volume with different weights occur in all series analyzed.

From the exploratory analysis, balances, weights, graduated, the ruler and the thermometer appeared to group together suggesting the basic components for a measurement in science unit. A frequency count was made in life science, earth science and physical science, and from three additional science textbooks to confirm the frequency of these instruments.

Frequency of each instrument was ranked. If the instrument appeared only once, it received a rank of 1; if it appreared twice, it received a rank of 2; and if the item appeared three times or more, it was assigned a 3. Measurement instruments with a frequency rank less than seven were not included in the summary sheet. Table 1 summarizes results of the ranking.

TABLE 1

Measurement Instrument Summary Sheet

MEASUREMENT INSTRUMENTS	TEXTS			AREAS			
	Everyday Problems in Science	The Physical World	Modern Physical Science	Physical Science (grade 9)	Earth Science (grade 8)	Life Science (grade 7)	Total for Texts and Areas
Thermometer	3	3	3	3	3	3	18
Balances	3	3	3	3	3	3	18
Weights	3	3	3	3	3	3	18
Ruler	3	2	2	2	2	3	14
Graduates	1	0	1	2	2	1	7

Results of Catalog Search

Examination of special aids and appliance catalogs for visually handicapped to ascertain the availability of measurement instruments indicate that a number of items are available. However, rulers, thermometers, balances, and other aids for measurement which were identified are not entirely suitable in their present state for illustrating tactually to blind children the operations as destribed herein.

Current commercial catalogs were examined to determine which measurement materials available for sighted children have utility for blind children or can be modified for their use. Many of the instruments and devices identified appear to require adaptation for use by blind students. A possible exception is the need for development of a ruler with inches and centimeters so arranged as to illustrate the comparison of units in the English and metric systems. Such supplementary aids as weights, graduates, and blocks of equal volumes do not require modification.

Summary

Seven sets of seventh, eighth and ninth grade science textbooks, including print and braille editions, were examined to identify basic measurement concepts presented and to identify the instruments used to illustrate them.

Basic science measurement operations were identified. They were categorized in the areas of life science, earth science, and physical science, and were found to overlap considerably throughout the grades.

Basic measurement operations are grouped under the following headings:

Linear measurement, using the metric and English system

Nature of energy and matter

Composition and general properties of matter

Meaning of volume and weight

States of matter

Changes in temperature

Mass and inertia

Gravity

Density

The instruments used to illustrate these operations were identified and those appearing most frequently were recorded. It was found that the following equipment can be used to illustrate and explain the above measurement operations:

Thermometer

Ruler, in inches and centimeters

Balances, spring and platform in grams and ounces

Weights

Graduates and various containers for measurement

Blocks of equal volumes with different weights

Examination of various specialized and commercial catalogs indicate that most of these measurement instruments are available commercially and it apprears that with adaptation they can be used effectively by blind children.

SPECIFICATIONS FOR DEVELOPMENT OF INSTRUMENTS USED TO DEMONSTRATE MEASUREMENT IN SCIENCE

With identification of basic measurement instruments accomplished, their development and/or adaptation for use by blind students became possible. Examination of the instruments indicated that the ruler, the spring balance, the pan balance and the thermometer would require adaptation while weights, blocks of equal volume and containers would not.

Problem

The purpose of this study was to prepare specifications for the production of tactile prototypes of each of the measurement instruments requiring adaptation. These would be used in a measurement in Science Kit (See APPENDIX for description of the Kit.) Where feasible, relevant findings from related literature and research studies are included in the specifications.

Review of the Literature

Two studies provide historical information of "graphics." Although these are not directly related to this project, they do provide historical information which may be of interest.

Henderson (1965) reviews history of materials and methods of raised line diagrams. His bibliography includes references from

the 1930's and the 1940's.

Mandola (1967), in a sampling of literature of the 1940's, found no attempt to support the value of developed aids by empirical evidence or by quoting research studies that might lend support.

Apparatus involving the use of bells, buzzers and vibrators occurs occasionally in the literature. Most of these occurrences in research projects are not sufficiently developed and tested for efficient use by the blind. Consequently no attempts have been made to use auditory displays in this project.

Mandola (1967) points up one of the most common errors made in the development of tactile aids: What is seen and understood--perceived--by the sighted will be perceived by the blind through the graphic aid. While efforts have been made to keep the aids developed as nearly as possible to their normal size, even greater efforts have been made to make tactile adaptations satisfy tactile needs rather than merely transferring visual symbols to tactile symbols.

While the search through the literature yielded little specific research in measurement in science, a number of related studies did point up findings relevant to certain aspects of the project. These findings are presented as they apply specifically to the individual measurement device developed or adapted.

Specifications

The ruler, in centimeters and inches. The ruler should be one foot, or a few centimeters longer than one foot. Suggested width is

one and one-half inches. This represents the minimum width face on which adequate spacing for braille and embossed lines can be placed. One of the purposes of the ruler is to teach the difference between the metric and the English system in measurement. Teaching this difference is facilitated by beginning centimeters (upper corner) and inches (lower corner) at the left end of the ruler and progressing to the right end. With this arrangement it is simple to illustrate the concept that two and one-half centimeters are equal to one inch approximately. To assure adequate reading of notations, no dimension smaller than one-half centimeter nor one-quarter inch is used. Each centimeter is divided into one-half centimeters and each inch into one-quarter inch divisions.

Schiff (1966) states that contrast is the most important principle for construction raised-line diagrams and that simplicity is possibly the second most important. For the construction of the ruler, emphasis has been on simplicity of design to keep down "tactile noise."

Schiff, Kaufer and Mosak (1967) suggested that if a diagram is fairly simple, there may not be a gain in using special symbols.

Essential features composed of linear, areal and point symbols are reduced to 1/8 and 3/8 inch raised lines .025 inches in height and to brailled number notations in centimeters and in inches.

The distance between lines is also an important consideration in constructing tactile diagrams. Wexler (1963) has stated that the eye can locate a point to within a distance of 0.625 mm. The finger requires a space four times that great. Schiff and Isikow (1966) found that a

difference of two milimeters between histograms was barely adequate and actually too small for efficient interpretation. Differences of more than 10% or more than two millimeters are desired for easily discriminable diagrams. Thus the 1/4 inch (some 6 millimeter difference between the 1/8 inch line and the 3/8 inch line apprears sufficient for easy discriminability.

A minimum rise of .025 inches was accepted for height of lines. Morris and Nolan (1967) found that seven linear symbols with an average relief of .022 inches as used in press made braille books met stringent criteria for discriminability. These seven were composed of some linear symbols more complicated than those used on the ruler. Neither did the authors find significant differences in ability to tactually identify these symbols between subjects at different chronological or at different grade levels, grades four through twelve.

The ruler is one-fourth inch thick in the center tapering down to one-eighth inch at the reading edges. The back of the ruler is hollow to allow flexibility and to reduce weight.

Braille notations occur at two centimeter intervals beginning with the second interval. Inch intervals also are labeled.

One-fourth inch (6 millimeters) minimum is allowed between the ends of the centimeter and inch lines and the braille notations, and three-eights inch mimimum between centimeter braille notations and inch braille notations.

<u>The (dial) spring balance, in grams and ounces</u>. The dial face for the spring balance consists of a complex radial display of raised lines and surfaces designating grams (in tens-of-grams) along the outer

perimeter and ounces within an inner circle. Schiff and Isikow (1966) have noted that as complexity of a tactile diagram increases, the details of the diagram are more likely to become confused.

Grams are indicated in 25 ounce raised line units along the perimeter with braille notations at every other 25 ounce designation. The raised lines are 3/8 inches long with a rise of .039 inches. Distance between lines in more than 6 millimeters.

To overcome the confusion caused by the shift from grams indicated along the outer perimeter to ounces indicated on the inner dial, contrast of the two sets of units is emphasized. Schiff and Isikow (1966) stated that as diagram difficulty increases, additional redundancy appears to play a role in reducing errors. Redundancy involves encoding a message so that it contains more symbols or stimulus features than the minimum necessary to transmit the information contained in the message. The authors concluded that the best mode of presentation in diagrams when "noise" is high is the textured and raised format--the most redundant. Thus contrast and redundancy are emphasized in the adaptation of the face of the spring balance.

Contrasts and redundancies built into the inner dial consist of the following:

> The surface of the ounce inner dial is textured of 40 grit background surface (Behr-Manning Metalite Cloth 'Lightening,' dark reddish-brown). Nolan and Morris (1965) found in a study of types of sandpaper used in the Roughness Discrimination tests that 60 grit was identified by 140 kindergarten through fourth grade subjects with only 6.4%

errors. Schiff (1966) found four grades of standard sandpaper readily discriminated by high school and college students. These grades of sandpaper, although discriminable when reproduced on Brailon in areas as small as 3/4 inches square, were less coarse than 60 grit sandpaper. Therefore, a 40 grit sandpaper was selected for the face of the inner dial to increase contrast and to overcome additional "noise' on the surface area.

This textured background was raised to a height of approximately .050 inches. This height provides an easily discriminable tactile boundary between grams and ounces. Gibson (1962; 1966) mentions the importance of distinctive tactile edges of some objects. Schiff (1966) considers the height of a tactile edge an excellent way of providing discriminable differences in area coding.

The textured background of the inner dial (ounces) is in contrast to the smooth surface of the outer perimeter (grams). The edge between the two further distinguishes the grams dial from the ounces dial. Rappaport (1957) found that stimulus redundancy aids perceptual performance... primarily when "noise" level is high.

The raised lines around the inner dial are approximately 1/2 inch in length with a rise of .039 inches. Greater differences in lengths of raised lines for grams and for ounces are unnecessary since no comparison of the lines is to be made.

Within the inner dial, touching the ends of the radii, is a smooth surface track upon which are located four tactile symbols (large raised dots, .050 inches high) which indicate 4, 8, 12 and 16 ounce conversions

for gram weights. In a study to establish minimum sizes at which certain tactual symbols can be recognized, Morris, Fieg and Nolan (1965) found that larger symbols (.20 inches) were easier to read than smaller symbols (.15 inches). Minimum size does not seem to be an issue in this instance since only one size dot is used. Largeness (inches across) and height of the dot are used here to further contribute to ease in identification and speed in performance.

The spring balance is designed for weighing in grams, although weighing in ounces can be accomplished. The design is such that the forefinger can be used to find measurements indicated by the needle, usually in grams. Then the second finger can be used as an anchor while the forefinger moves across the tactile boundary to the raised ounce indicators. The third finger can be employed if necessary for holding the original place as the forefinger moves to the smooth center track and the second finger follows over the tactile boundary.

Henderson (1965) developed a spring balance on which he "magnified scale size by a factor of four." Supplementing tactile discrimination with audible clicks, he increased the accuracy of his balance. Wexler (1963), using three different spring balances, weighs 100 grams to within 1 gram, 10 grams to within 0.1 gram, or 1 gram to within 0.01 gram. However, use of these devices take three to five times as long as ordinary measurements, and while accuracy is increased, no additional contribution to the teaching of measurement concepts is indicated. The complexity involved in achieving greater accuracy may in fact complicate the initial "concept learning" process.

The pan balance, in grams. The face for the pan balance is less complex than that of the dial spring balance. The pan balance is a

more accurate measurement instrument than the spring balance. An object of unknown weight is placed in the left tray and balanced with known weights placed in the right tray. An indicator or needle rests on a center point or line on the face of the scale when the trays are in balance.

The raised line on the smooth foreground of the face of the prototypes has a rise of approximately .039 inches. The smooth foreground is raised .020 inches on the same 40 grit background as used on the spring balance. When the needle rests on the center line, it indicates "perfect" balance. If the needle is "in the rough" then weight must be added to or subtracted from the right hand tray to achieve balance.

By placing the pulp of the finger on the center line, the balance of the trays can be felt when the needle is on the line. If the needle is off, the amount of difference and the position of the needle can be detected by slight manipulation of the pulp of the finger.

The Fahrenheit (dial) thermometer. The face of the dial thermometer is three inches in diameter. Approximately two and one-quarter inches consist of the indicator needle and large black numerals, 24 point or larger, printed on a white base. Around the outer edge approximately one-fourth inch above the base is the tactual portion of the face. Almost one-quarter of the outer edge is lost in the rim. Consequently, only one-fourth inch remains for the tactile portion of the face. Temperature is indicated in ten

degree units by one-fourth inch lines that are approximately .039 inches high.

Both freezing point (32° F) and boiling point (212° F) are marked with a large braille dot some .050 inches high. Morris and Nolan (1964) cautioned against using certain point symbols and warned that blind students may have difficulty in recognizing differences in varying sizes of embossed dots on paper if they appear in combination with each other or with certain other symbols. Since the large embossed dot is the only point symbol used on the prototype face, it is used with some confidence. Primary consideration is whether or not the dot is easily distinguished from embossed lines around the perimeter.

The interval from 70 to 80 degrees Fahrenheit is indicated by a rough surface (40 grit sandpaper as described previously) raised to approximately .040 inches.

The thermometer is designed to indicate temperatures ranging from below freezing to boiling point, with emphasis on indicating points at which phase changes in matter occur. Although the thermometer was not designed for general use, it can be used to perform a number of activities in measuring temperature. The ten degree interval between 70 and 80 enables students to measure liquids at room temperature and serves as a reference point between freezing and boiling points.

Summary

A set of measurement in science materials was identified through curriculum analysis. Four of the measurement instruments--the ruler,

the dial spring balance, the pan balance and the thermometer--required adaptation and/or development.

A review of the literature yielded little specific research in measurement in science. However, results from a number of studies did provide information relevant to certain aspects of development of the instruments. Where feasible, this information was implemented in development of the tactile faces of the above instruments which required adaptation.

Adaptations were kept as simple as possible. Less sophisticated devices are required to illustrate and explain the basic measurement concepts identified in the textbook analysis than are required to perform the more precise operations that appear in advanced science textbooks.

Efforts were made to adapt in consideration of the tactile needs of the blind student rather than translating *per se* visual symbols to tactile symbols.

Weights, blocks of equal volume and containers such as the overflow can and catch can which did not require adaptation were purchased from commercial sources to complete the Measurement in Science Kit.

EVALUATION OF MEASUREMENT IN SCIENCE INSTRUMENTS

With adaptation and development of the ruler, the spring balance, the pan balance and the thermometer accomplished, evaluation of these instruments became necessary.

Problem. The purpose of this project was to determine if blind children at the junior high level and at the upper elementary level can successfully perform tasks in measurement which indicate their ability to read the tactile faces and raised surfaces on the measurement instrument prototypes.

Subjects. Of the 70 subjects used in the study, 51 were junior high and 19 were elementary students. The 51 junior high students consisted of 10 ninth, 23 eighth, and 18 seventh grade students. The 19 elementary subjects were composed of 13 sixth grade, 4 fifth and 2 fourth grade students. All students were braille readers enrolled in regular classes in residential schools for blind children. No specific criteria for age and IQ were set.

Procedure. Twenty tasks were selected for use in evaluating each student's ability to read the tactile faces and surfaces of the ruler, spring balance, pan balance and thermometer. (The tasks are included at the end of this section.) A three-step procedure for evaluating suitability of the devices for blind students was followed:

1) Introduction. The use of each instrument and the construction of each tactile face were explained. The operation of each

instrument was explained, and students were given opportunity to examine each one tactually.

2) Review. Each measurement instrument was reviewed. The examiner was present to clarify points and to answer questions which teachers and/or students had. Instruments were again circulated and students were permitted to perform simple measuring and weighing exercises which involved reading the tactile faces.

3) Evaluation. The twenty tasks were performed by students in individual sessions, and answers were recorded on answer sheets.

The total time involved in accomplishing these three steps ranged from four sessions for small groups to six sessions for large groups. No time limits were set in performance of tasks since ability to perform was emphasized over time required to perform the tasks.

The twenty tasks used in evaluation follow.

(A copy of the complete set of instructions and exercises in the Measurement Kit is included in the appendix.)

Ruler

1) Using the ruler as guide, convert the following centimeters to the approximate value in inches:

a) 2 1/2 cm = _____ in
b) 5 cm = _____ in
c) 28 cm = _____ in
d) 9 1/2 cm = _____ in
e) 21 cm = _____ in

2) Convert the following inches to centimeters:

a) 10 in = _____ cm
b) 5 3/4 in = _____ cm
c) 9 1/4 in = _____ cm
d) 1 in = _____ cm
e) 3 3/4 in = _____ cm

Spring Balance

Using the face of the spring balance, answer the following questions:

a) 125 grams is almost _____ounces (to the nearest ounce indicated).
b) 250 grams is (more, less) than eight ounces.
c) Twelve ounces is nearer which of the following: 325 grams, 350 grams or 375 grams?
d) 375 grams is approximately _____ounces.
e) 500 grams is (more, less) than 17 ounces.

Pan balance

Using the pan balance, weigh the following items:

a) plastic specimen
b) brass specimen
c) aluminum block

Thermometer

1) What is the approximate room temperature of the water in which the thermometer is standing?

2) What is the temperature reading of the thermometer which is standing in the container of ice?

Overall Results. The overall percent mastery for the four measurement devices with 70 Ss was better than 80%. A breakdown of percentages for these instruments is given in Table 1.

TABLE 1

Individual and Overall Mastery
for Measurement Instruments

Ruler	Spring Balance	Pan Balance	Thermometer	Total
79%	86%	80%	99%	84%

Junior high and elementary school groups compared. Junior high Ss as a group demonstrated a mastery of 85.7% as compared with 82.4% by elementary Ss as a group. The junior high group was composed of 51 seventh, eighth and ninth grade students, and the elementary group was composed of 19 fourth, fifth and sixth grade students. A comparison of the two groups is given in Table 2.

TABLE 2

Mastery of Junior High and
Elementary School Groups Compared

	Age	IQ	Ruler	Spr. Bal.	Pan Bal.	Therm.	Total	
Jr. Hi.	14.6	105.7	16.3	8.4	4.9	3.9	34.3	Average
			81.5	83.5	82.7	99.0	85.7	%
Elem.	12.2	102.1	15.4	8.8	4.7	4.0	32.9	
			76.8	88.4	78.0	100.0	82.4	

Difference in mastery for the two groups does not appear to be significant when differences in average age and average IQ are considered. Results seem to indicate that even elementary school students can read the tactile faces well enough to perform the measurement in science experiments and activities included in the Kit.

Observations

This study evaluated measurement instruments and not measurement concepts, although the instruments tested are designed to illustrate basic measurement concepts. While knowledge of measurement concepts cannot be evaluated directly from the tasks presented in the test used, analysis of data and observation of behavior in the testing situation are suggestive.

Although differences in overall mastery scores between junior high and elementary school groups do not appear to be significant, junior high students performed better than elementary students.

The junior high students as a group:

a) had less difficulty in discriminating the raised areal, linear and point symbols used on the faces of the measurement instruments

b) indicated greater exposure to the kinds of measurement instruments tested,

c) expressed more interest in the range and variety of uses of the instruments,

d) appeared to have a better grasp of such concepts as length, weight, balance and degrees of temperature,

e) were more familiar with inch-centimeter and ounce-gram relationships, and

f) relied more extensively on abstract knowledge in performing the concrete operations presented in the test.

Conclusions

1. A high level of performance was achieved by both the elementary and the junior high groups. Overall performance, and performance for each group, exceeded 80% mastery on the instruments tested.

2. The older students, male and female, generally performed better and achieved higher mastery scores than younger students.

3. The less complicated the tactile arrays on the faces of the measurement instruments, the higher the percent of mastery.

4. Contrast and redundancy employed in the development of the faces of the more complex instruments enabled students to achieve high percentages of mastery.

5. The elementary group appeared to have less developed measurement concepts than the junior high group, but were able to achieve high mastery scores on the test because the tasks emphasized concrete operations.

6. The junior high group which achieved a higher overall score than the elementary group in performing the same operations appeared to rely upon knowledge of a more abstract nature in approaching the tasks.

Summary

Four measurement instruments (ruler, spring balance, pan balance, thermometer) were identified through curriculum analysis and were developed and adapted implementing results from relevant research. The instruments were field tested using 70 subjects, 51 junior high and 19 elementary school students, grades four through nine. All students were braille readers from residential schools for blind children.

Overall percent of mastery of the devices exceeded 80%, and ranged 79% mastery for the ruler, 86% for the spring balance, 80% for the pan balance, and 99% for the thermometer.

The high level of performance achieved by both groups on the test indicates that elementary and junior high students can read the tactile table faces on the instruments well enough to perform the operations required by the activities and experiments included in the Measurement in Science Kit.

REFERENCES

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APPENDIX

MEASUREMENT IN SCIENCE KIT

To open the Kit, remove the detachable lid or cover, and leave the case sitting upright. The ruler and the spring balance are attached to the inside of the cover.

The pan balance and the overflow can are located on the top shelf. The pan balance is on the left-hand side and can be removed for use. On the right-hand side is the overflow can which contains the catch can. The thermometer stem extends up through a groove in the top shelf. This shelf is removable.

The bottom shelf contains weights, blocks and the thermometer. This tray can be removed for convenience.

The weight container is on the left side of the tray. Gram weights are in two rows. Weights begin with on gram, left-front, and continue around the container, counter clockwise, to the 500 gram weight which is located behind the 1 gram weight. There are two each of the 2, 10 and 100 gram weights.

Next are two rows of four 1 1/4 inch square blocks. The blocks in front are aluminum (labeled a), iron (labeled i), brass (b), and lead (l). The second row behind from left to right are: balsa, cork, pine, and oak blocks. These blocks range in weight from lightest to heaviest.

The Fahrenheit thermometer is next, face down, with the stem extending up through a groove in the second shelf.

On the extreme right are the specific gravity specimens. From front to back are: aluminum, iron, brass and lead. Each is one cubic inch in size.

An electric heater is included in the Kit.

Instrument

Ruler, in inches and centimeters

Purpose

To provide experiences in measuring dimensions of items in the Kit, to familiarize the student with the various measurement devices to be used in exercises and experiments that follow and to teach the difference between the metric and the English system in measurement.

Measurement activities

1) Using the ruler as a guide, convert the following centimeters to the approximate value in inches:

(a) 2 1/2 cm = _____ in.
(b) 5 cm = _____ in.
(c) 28 cm = _____ in.
(d) 9 1/2 cm = _____ in.
(e) 21 cm = _____ in.

2) Convert the following inches to contimeters:

(a) 10 in = _____ cm.
(b) 5 3/4 in.= _____ cm.
(c) 9 1/4 in.= _____ cm.
(d) 1 in.= _____ cm.
(e) 3 3/4 in.= _____ cm.

3) Measure to the closest half-centimeter the following items in the Kit:

(a) Thermometer stem _____
(b) Depth of catch can _____
(c) Depth of overflow can _____
(d) Length of pan balance tray (edge to edge) _____
(e) Width of pan balance tray (edge to edge) _____
(f) Approximate length of the base of the pan balance _____
(g) Diameter of the bottom of each of the following weights:

(1) 500 gram weight _____
(2) 200 gram weight _____
(3) 100 gram weight _____
(4) 10 gram weight _____
(5) 1 gram weight _____

Instrument

The (Dial) Spring Balance, in grams and ounces

Purpose

To teach the use of the spring balance in measurement of approximation of weights of objects and for teaching the conversion of grams to ounces.

Concepts and generalizations

1. The spring balance can be used to illustrate measurement of the pull of gravity.

2. The weight of an object can be easily approximated by hanging it from a spring balance.

Exercises

1. Using the face of the spring balance, answer the following questions:

(a) 125 grams is almost _____ounces (the nearest ounce indicated).
(b) 250 grams is (more, less) than eight ounces.
(c) Twelve ounces is nearer which of the following: 325 grams, 350 grams or 375 grams?
(d) 375 grams is approximately _____ounces.
(e) 500 grams is (more, less) than 17 ounces.

2. Examine the four 1 1/4 inch metal blocks. In order of weight from lowest to highest they are:

(a) aluminum
(b) iron
(c) brass
(d) lead

Using the spring balance, approximate to the nearest gram-weight indicate the weight of each of them.

Additional activities

1. Attach the ring of the balance to a nail or peg. Then pull the hook downward slowly measuring, in ounces, the force exerted by the pull of the hand. Repeat until you are able to find, 4, 8, 12, and 16 ounces rapidly.

2. Measuring the pull of gravity of an object is the same as determining the object's weight. Select several common objects, weigh them, and record their weights in grams.

3. How many grams are there in an ounce?

Instrument

The Pan Balance, in grams

Purpose

To teach the use of the pan balance when more accurate measurements than those afforded by the spring balance are required.

Concepts and generalizations

1. If an object is placed on the left pan and is balanced by weights on the right, the earth's gravitational force is the same for both--the two forces are the same for each pan.

2. The weight of the body in the left pan is indicated by the total amount of weight in the right pan.

Exercises

1. Using the pan balance, weight each specific gravity specimen. From lowest to highest weight they range:

(a) aluminum
(b) iron
(c) brass
(d) lead

Additional Activities

1. Using the spring balance, reweigh the 1 1/4 inch metal blocks. Record the weights. Now weigh each on the pan balance. Record the weights. Compare the weights. What differences in the weights of the blocks do you notice? What is the explanation for these differences?

Instrument

The Farenheit (Dial) Thermometer

Purpose

To provide blind students an instrument for measuring changes in temperatures of water from freezing to boiling point and for tactually observing changes in temperature that occur during phase changes in matter.

Concepts and generalizations

1. Water exists in the environment in all three states of matter: solid (ice), liquid (water), and gas (water vapor). Whenever one state changes into another, heat is gained or lost. These changes in heat can be measured.

2. Condensation (dew) may form on anything that has a temperature which is lower than the dew point of the air that touches it, if the temperature at which condensation is taking place is above 32°.

3. When ice is placed in water, heat from the water is given off into the air. The temperature of the water decreases until it reaches freezing temperature (32°).

4. Evaporation is a cooling process during which temperature decreases.

5. Frost will form if the temperature at condensation is below 32°.

6. When heat is removed from water, it gets steadily colder until it reaches 32°. The water stays constant at this temperature until all of the water is frozen. Temperature begins to drop again if more heat is removed.

7. When salt is mixed with ice in a container, the temperature of the mixture drops low enough to cause an inserted test tube partially filled with water to freeze solid, although the mixture surrounding the test tube becomes less solid.

Experiments

1. Measure changes in temperature from room temperature to ice-in-water to boiling point.

Place the thermometer in the overflow can, one-half filled with water which has been allowed to stand at room temperature for several hours. Leave the thermometer in the water until the temperature reading is constant. This is water at room temperature. Record it. (a) _____.

Put several pieces of ice in the can and stir. When the temperature is constant, record it. (b) _____.

What happens to the temperature of the water as the ice melts?

(c) _____

How low does it go? (d) _____.

Heat the container slowly stirring the mixture. Take the temperature at intervals until all of the ice is melted and the temperature again remains constant. What happens to the temperature of the water after the ice has melted? (e) _____

How high does the temperature go? (f) _____

Additional experiments

1. Place several pieces of ice in a beaker (glass container) of water. Stir the mixture. Examine the outside of the beaker to determine at what temperature the first mist of drops of water appear. Record the temperature. What is the explanation of the appearance of the mist?

2. Put three parts of cracked ice and one part salt in the overflow can. Submerge all but one-fourth inch of a test tube partially filled with water in the can. Insert the thermometer in the test tube. Observe and record the temperature every half minute until the content is several degrees below freezing. Does the water keep getting colder while it is freezing? At what temperature reading does it remain constant? Why?

Examine the frost on the outside of the overflow can. What is the explanation for its appearance?

When the test tube is removed from the can and the thermometer is removed from the test tube, measure the temperature of the contents of the can. Compare the lowest temperatures of the test tube contents with the lowest temperature of the contents of the can. Which is lower? Why didn't the mixture in the can freeze solid? Explain.

ADDITIONAL UNIT--VOLUME, DENSITY, GRAVITY

Instrument

Overflow Can and Catch Can

Purpose

To teach the determination of volume of small irregular objects by liquid displacement and to further illustrate density and gravity.

Concepts and generalizations

1. Two objects cannot take up the same space at the same time.

2. The apparent loss of weight of an object placed in a container of water is equal to the weight of the liquid displaced.

3. Specific gravity is the weight of an object divided by the weight of an equal volume of water. It is the ratio of a solid or liquid to the density of water.

4. If the density of an object is greater than that of water, the object sinks.

5. If the density of an object is greater than that of water, the object floats.

6. Fluids push up on objects immersed in them. Bouyancy is the name given to this force.

Exercises

1. Fill the overflow can. Place the catch can under the spout. Lower an object into the can. The amount of water displaced by the object is the volume of the object, when its density is greater than that of water.

2. What is the specific gravity of water? Which of the 1 1/4 inch blocks have specific gravities greater than water? Which blocks float? Which ones sink?

   Using the spring balance -

3. Weigh those blocks with specific gravities greater than water. Record the weights. Using a string attached to the spring balance, weigh each of these blocks in water. Record the weights. The weight of the block in the air less (minus) the weight of the object in water should equal the weight of the water displaced by the block. Check the weights of each to determine if this is true.

4. Explain Archimede's principle. Using the appropriate blocks, illustrate this principle.

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